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Laser Illumination of Aircraft by Geographic Location for a 3-Year Period (2004–2006)

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16. Abstract

INTRODUCTION: Incidents involving laser illumination of aircraft in the National Airspace System have raised concerns within the aviation community for more than a decade. The principal concern is the visual effect laser illumination may have on flight crew performance during terminal operations, such as landing and departure maneuvers, when operational activities are extremely critical. This 3-year study examines the frequency and rate of aviation-related laser incidents by year and location. **METHODS:** Incident reports of civilian aircraft illuminated by high-intensity lights have been collected from various sources and entered into a database maintained by the Vision Research Team at the Civil Aerospace Medical Institute. Reported incidents of laser exposure of civilian aircraft in the United States for a 3-year period (January 1, 2004 to December 31, 2006) were collated and analyzed. **RESULTS:** A total of 832 incidents during the study period took place within the United States in the nine FAA-designated regions. For the period, total laser incident rates per 100,000 flight operations ranged from zero in the Alaskan region to 0.86 in the Western Pacific Region. Of the 202 airports where laser incidents occurred, there were 20 (9.9%) that reported 10 or more laser incidents during the study period. The majority of airports (52.6%) with 10 or more laser incidents reported a higher number of incidents in 2005 than in 2006. **CONCLUSION:** Laser illumination incidents that could compromise aviation safety and threaten flight crew vision performance occur with some regularity within the contiguous United States. While the study data indicate the Western Pacific Region had a significantly higher prevalence rate than the other FAA regions, analysis was complicated by incident clusters that occurred randomly at various airports. Actions taken by aviators, as well as local air traffic and law enforcement authorities that can minimize this threat to aviation safety, are discussed.

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Laser Illumination of Aircraft by Geographic Location for a 3-Year Period (2004–2006)

BACKGROUND

Incidents involving laser illuminations of civilian and military aircraft in the National Airspace System (NAS) have raised concerns within the aviation community for more than a decade. The principal concern is the effect laser illumination may have on flight crew performing terminal operations, such as landing and departure maneuvers, when operational requirements are critical. During these maneuvers, distraction or visual impairment of any kind has the potential to degrade flight performance, disrupt cockpit procedures, crew coordination, and pilot and air traffic control communications.

Pilot visual workload is task-dependent and changes according to the phase of flight. Below 10,000 feet, the Code of Federal Regulations (CFR) require a "sterile cockpit" (i.e., only operationally relevant communication) that minimizes distractions and reduces the potential for flight procedure errors. Below 1,000 feet, the aircraft must be in a landing configuration and in position to complete a normal landing. To continue the descent below the descent minimums for a particular instrument approach procedure, crewmembers must be able to visually identify the runway threshold and/or runway/approach lights. If these configurations are not visually identifiable, the pilot must execute a go-around (1,2,3,4).

The Federal Aviation Administration (FAA) has led efforts to protect flight crewmembers and the flying public from the effects of laser exposure. Prior to 1995, laser operators were allowed to project laser beams into the navigable airspace as long as these beams did not exceed the limit imposed by FAA Order 7400.2 (Procedures for Handling Airspace Matters) (5). This order was originally written in terms of the Food & Drug Administration's (FDA's) "Performance Standards for Light-Emitting Products," Title 21 CFR 1040 (6). The FDA standard is based on the Maximum Permissible Exposure (MPE) of 2.54 milliwatts per square centimeter (mW/cm^2), above which ocular tissue damage may occur from exposure durations longer than 0.25 second. The recommended MPE limit was developed by the American National Standards Institute (ANSI Z-136.1-2007) (7). The MPE is used to calculate the Nominal Ocular Hazard Distance (NOHD), which varies depending on the laser's output power, pulse duration, wavelength, and beam divergence.

In 1995, FAA Order 7400.2, Part. 6 (Miscellaneous Procedures), Chapter 29 (Outdoor Laser Operations) was revised to establish lower laser exposure levels for protecting flight crew from adverse effects in specific zones of airspace around airports (5). These effects include annoyance, momentary distraction, and visual effects, such as:

- Flashblindness – A temporary visual interference effect that persists after the source of illumination has ceased (5).
- Afterimage – A reverse contrast shadow image left in the visual field after an exposure to a bright light that may be distracting and disruptive, and may persist for several minutes (5).
- Glare – Obscuration of an object in a person's field of vision due to a bright light source located near the same line-of sight (e.g., as experienced with oncoming headlights) (5).

In the years following this action, a substantial decrease in the number of reported laser illumination incidents[1] was observed.

However, during the fall/winter of 2004 and January of 2005, there was a marked increase in reported laser incidents. These incidents were not the accidental illuminations attributed to outdoor laser light shows, which FAA Order 7400.2 was modified to mitigate. They appeared to be random acts by individuals using handheld lasers. In response to the rapid increase in laser incidents, on January 12, 2005, then Secretary of Transportation, Norman Mineta, held a press conference at the FAA's Civil Aerospace Medical Institute (CAMI) in Oklahoma City (Figure 1), to announce the publication of an Advisory Circular (AC), entitled "Reporting of Laser Illumination of Aircraft," (AC No. 70-2) (8). The AC includes a "Suspected Laser Beam Exposure Questionnaire" to be filled out by exposed aircrew member(s) and provide quantifiable data to better define the nature of the threat and its effect on civil aviation operations (see Appendix A). A better understanding of the problem provides a mechanism for developing more meaningful mitigation

[1]Although the incidents of laser exposure discussed in this paper are often consistent with the definition of an aircraft incident, as defined by the FAA and NTSB (i.e., ***Incident.*** An occurrence, other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation), the laser exposure incidents discussed in this paper are not necessarily included in the official FAA AIDS or NTSB Accident/Incident databases.

Figure 1. *The Secretary of Transportation, Norman Mineta, holding a press conference at the FAA's Civil Aerospace Medical Institute in Oklahoma City to announce the publication of AC No. 70-2 (Reporting of Laser Illumination of Aircraft).*

procedures. It is also the first step in improving coordination between local and federal law enforcement agencies in apprehending and prosecuting violators.

This investigation utilizes information contained in a database of laser exposure incidents maintained by the Vision Research Team at CAMI. Its purpose is to expand on a previous FAA report (9) that reviewed lasing incidents over a 13-month period (January 1, 2004 – January 31, 2005). This study examines the frequency and rate of lasing incidents by year for a 3-year period (2004-06) and by location. It also discusses issues that Aviation Medical Examiners (AMEs) and eyecare practitioners should be aware of when consulting with pilots concerning the potential hazards of laser exposure.

METHODS

Reports of high-intensity light illumination of civilian aircraft were collected from various sources, including: FAA regional offices, Transportation Security Administration (TSA), Department of Homeland Security/Federal Bureau Investigation Information Bulletin, the FAA's Office of Accident Investigation, newspaper articles, and personal interviews with reporting and investigating personnel. Details from these reports were entered into a computer database maintained by CAMI's Vision Research Team. Reports involving laser exposure of civilian aircraft in the United States were collected for the 3-year period (January 1, 2004, to December 31, 2006).

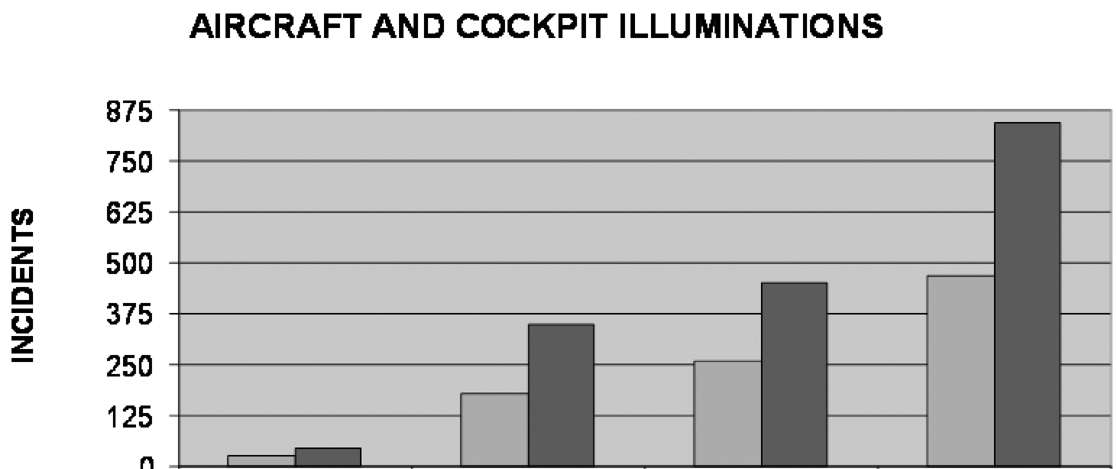
Analysis involved stratification of incident data by location (regions and airports) for each year of the study and calculating incident rates per 100,000 flight operations (arrivals and departures). The number of flight operations for individual regions and airports were obtained by accessing the Air Traffic Activity Data System (ATADS) (10). The ATADS contains daily, monthly, and annual traffic counts that are drawn from the Operations Network (OPSNET) system.

In addition, other operational and visual effect data contained in the laser incident reports were collated and analyzed to provide a better understanding of the safety issues associated with the illumination of aircrew personnel by lasers during critical phases of flight.

RESULTS

There were a total of 845 incident reports collected for the study period. Of these, 467 (55.3%) involved laser exposure incidents in which the cockpit environment was actually illuminated (Figure 2).

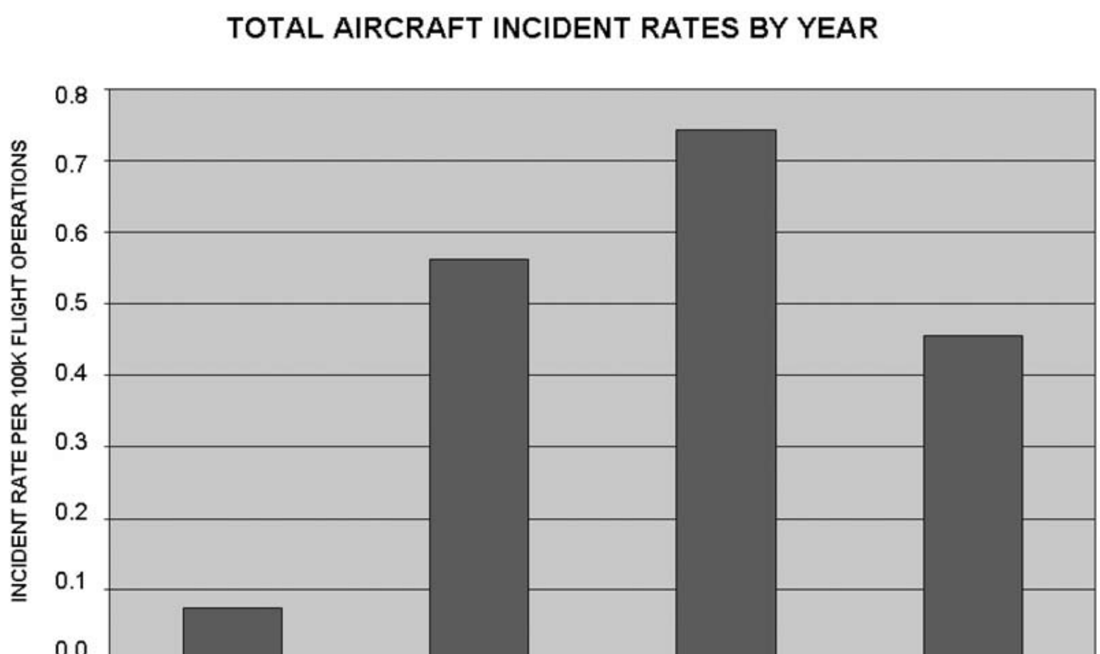
Of the 845 total, 832 (98.5%) laser incident reports took place within the United States and included 41 different states. Of the remaining incidents, 12 occurred in foreign countries and one in the Territory of Puerto Rico. Only the incidents that took place within the United States were included in the subsequent data analysis. Figure 3 shows the rate of aircraft illuminations per 100,000 flight operations by year and for the study period.



	2004	2005	2006	TOTAL
Cockpit	29	179	259	467
Aircraft	46	348	451	845

YEAR

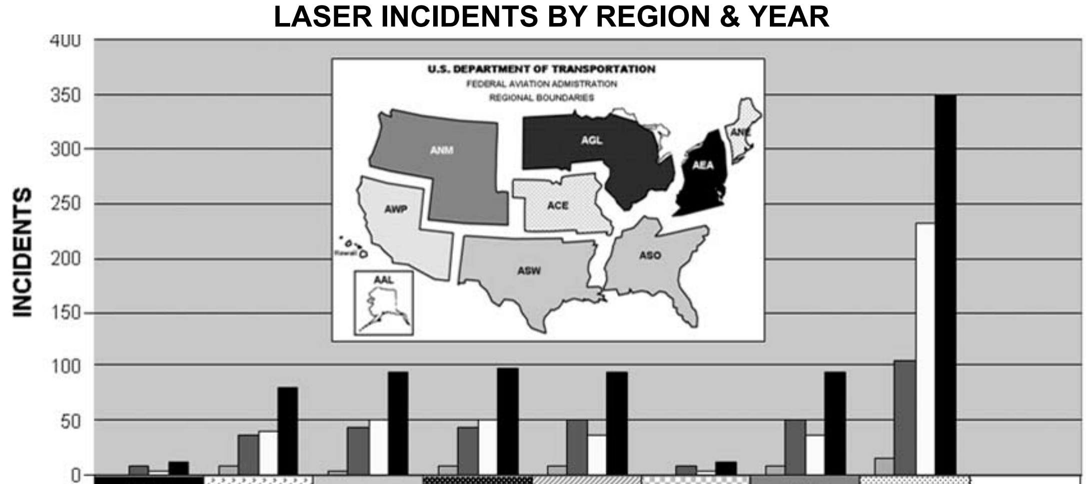
Figure 2. *Reports of laser illuminations that entered the cockpit increased by 793% (29 – 259) while the total number of aircraft illuminations increased 880% (46 – 451) for the study period.*



	2004	2005	2006	PERIOD
TOTAL	0.07	0.55	0.74	0.45

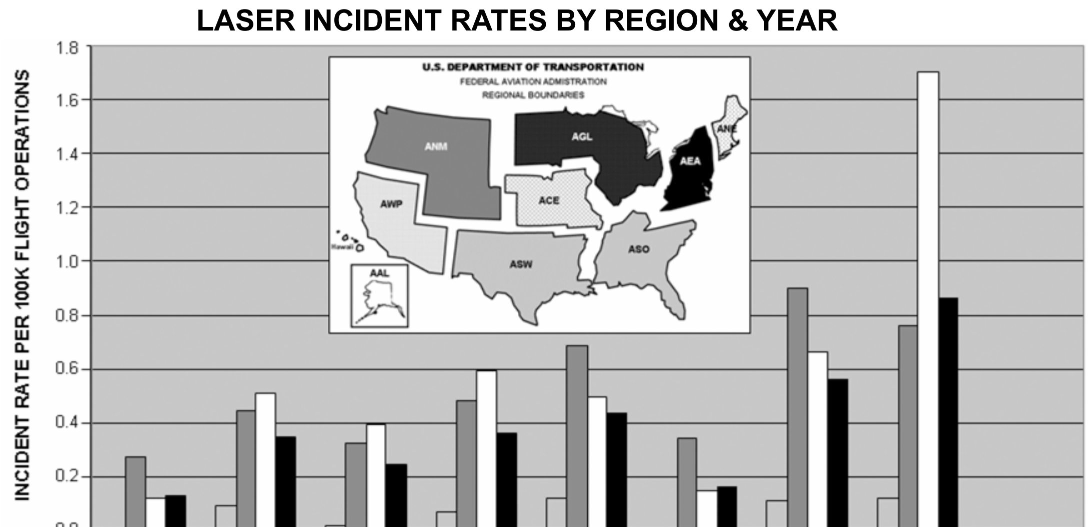
YEAR

Figure 3. *The total rate of laser incidents increased 957% for the period (0.07 – 0.74).*



	ANE (NEW ENGLAND)	AEA (EASTERN)	ASO (SOUTHERN)	AGL (GREAT LAKES)	ASW (SOUTH WEST)	ACE (CENTRAL)	ANM (NORTHWEST MOUNTAIN)	AWP (WESTERN PACIFIC)	AAL (ALASKAN)
2004	0	7	2	6	9	0	6	16	0
2005	7	35	43	42	50	7	50	104	0
2006	3	39	50	49	36	3	37	231	0
TOTAL	10	81	95	97	95	10	93	351	0

Figure 4. *The Western Pacific Region reported the most laser incidents (351, or 42.2% of the total), while the Alaskan Region reported none. The Southern Region exhibited the greatest percentage increase in laser incidents (2400%) during the 3-year period.*

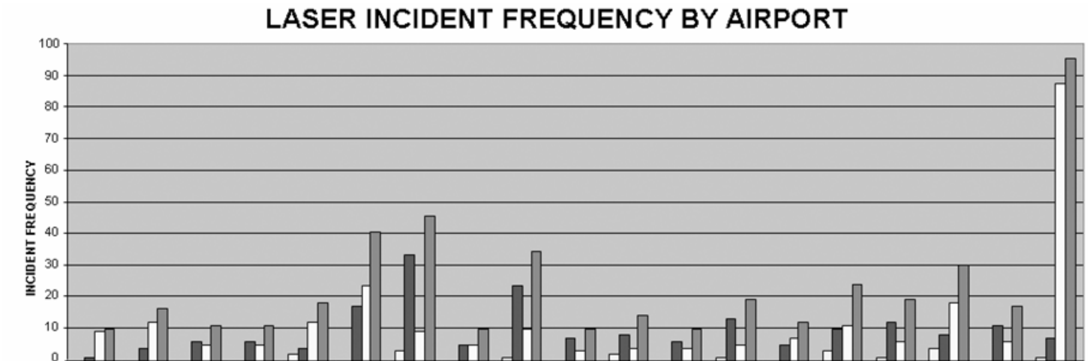


	ANE (NEW ENGLAND)	AEA (EASTERN)	ASO (SOUTHERN)	AGL (GREAT LAKES)	ASW (SOUTH WEST)	ACE (CENTRAL)	ANM (NORTHWEST MOUNTAIN)	AWP (WESTERN PACIFIC)	AAL (ALASKAN)
2004	0.00	0.09	0.02	0.06	0.12	0.00	0.11	0.12	0.00
2005	0.27	0.44	0.33	0.48	0.69	0.34	0.90	0.76	0.00
2006	0.12	0.51	0.39	0.59	0.50	0.15	0.66	1.71	0.00
TOTAL	0.13	0.34	0.24	0.36	0.43	0.16	0.56	0.86	0.00

Figure 5. *The Western Pacific Region exhibited the highest laser incident rate (0.86), followed by the Northwest Mountain Region (0.56). AWP also had the highest incident rate for a single year, at 1.71 in 2006.*

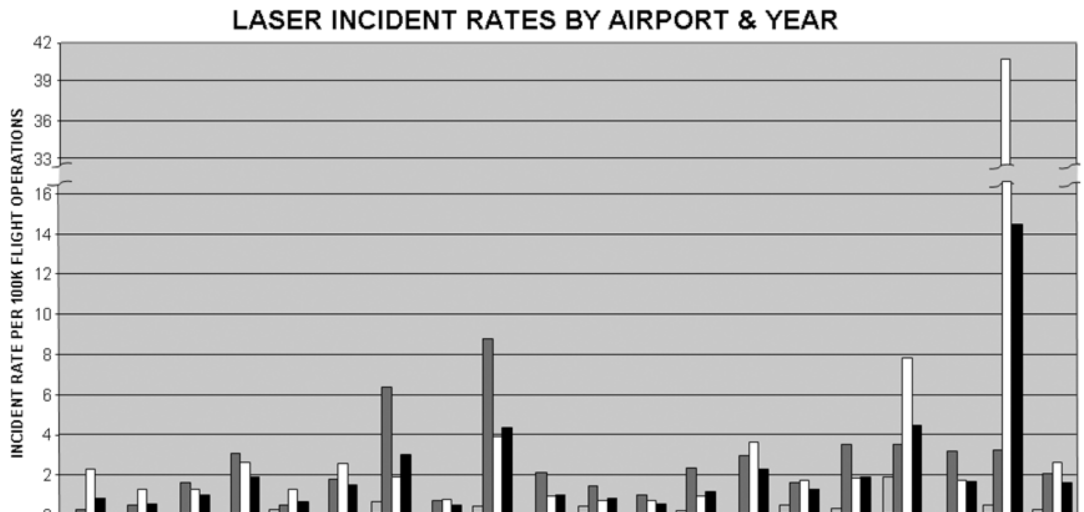
Figure 4 provides the number of laser incidents that occurred in each of the nine FAA regions within the United States. Every region, except the Alaskan, reported 10 or more laser incidents during the study period.

The laser incident rates per 100,000 flight operations for each region (by year and for the period) are reported in Figure 5. For the period, total laser incident rates ranged from 0.00 in the Alaskan Region to 0.86 in the Western Pacific Region. Analysis of Variance (ANOVA) found significant variation between the years ($p = 0.003$) and between the regions ($p = 0.03$).



	La Guardia	Atlanta	Miami	West Palm Beach	Chicago	Detroit	Dallas/ Ft Worth	Portland	Seattle/ Tacoma	Denver	Salt Lake City	Las Vegas	Phoenix	Burbank	Los Angeles	Oakland	San Diego	San Francisco	San Jose
2004	0	0	0	0	2	0	3	0	1	0	2	0	1	0	3	1	4	0	1
2005	1	4	6	6	4	17	33	5	23	7	8	6	13	5	10	12	8	11	7
2006	9	12	5	5	12	23	9	5	10	3	4	4	5	7	11	6	18	6	86
TOTAL	10	16	11	11	18	40	45	10	34	10	14	10	19	12	24	19	30	17	94

Figure 6. *The chart includes 19 airports that reported 10 or more laser incidents during the period.*



	La Guardia	Atlanta	Miami	West Palm Beach	Chicago	Detroit	Dallas/ Ft Worth	Portland	Seattle/ Tacoma	Denver	Salt Lake City	Las Vegas	Phoenix	Burbank	Los Angeles	Oakland	San Diego	San Francisco	San Jose	Total
2004	0.00	0.00	0.00	0.00	0.20	0.00	0.57	0.00	0.38	0.00	0.35	0.00	0.17	0.00	0.46	0.29	1.86	0.00	0.45	0.21
2005	0.25	0.41	1.57	3.03	0.41	1.75	6.31	0.70	8.77	2.05	1.41	0.98	2.31	2.89	1.54	3.45	3.49	3.11	3.19	1.99
2006	2.22	1.23	1.29	2.59	1.25	2.40	1.87	0.71	3.84	0.88	0.66	0.65	0.91	3.58	1.67	1.79	7.80	1.67	40.75	2.56
Total	0.82	0.55	0.94	1.86	0.62	1.37	2.95	0.45	4.32	0.96	0.80	0.55	1.12	2.22	1.22	1.86	4.44	1.59	14.41	1.58

Figure 7. *For the majority (52.6%), laser incident rates were highest in 2005. The disproportionately high number of incidents reported for San José airport (40.8) resulted in a higher total incident rate for 2006 (2.56).*

Of the 202 airports where laser incidents occurred, there were 20 (9.9%) that reported 10 or more laser incidents during the study period. Nineteen of these airports are represented in Figure 6. Although Moffett Airfield, an airport operated by NASA Ames located near Mountain View, CA, reported 10 incidents for the period, it was omitted from this comparison since flight operations data were unavailable. The majority of airports (52.6%) reported a higher number of incidents in 2005 than in 2006. However, the total number of laser incidents reported for the year 2006 (240) outnumbered the totals for both 2004 and 2005 (18 and 186, respectively), principally due to the large number of incidents (n=86) reported for the Mineta San José International Airport in California.

Incident rates for these airports are presented in Figure 7. The overall incident rate increased for each year of the study. The San José airport had the highest total rate of 14.41 incidents per 100,000 flight operations. However, ANOVA found no significant variation ($p > 0.05$) in rates for each year of the study or for the average difference in the rates of these airports.

DISCUSSION

In the two decades prior to the issuance of AC No. 70-2, several hundred aircraft laser illuminations have been reported (11). These reports were frequently not forwarded to the proper authorities in a timely manner, and the information they contained were often vague or incomplete. As a result, data collection and follow-up investigations were difficult to analyze. Since January 12, 2005, laser incident reports have been more detailed, and coordination with local aviation and law enforcement authorities has improved. The data collected over the past 3 years, particularly in 2005 and 2006, provide a more precise depiction of the laser illumination problem.

A previous FAA study (9) described a rapid increase in the number of laser exposure incidents involving civilian aircraft for a 13-month period (January 1, 2004, to January 31, 2005). It suggested that the increase in incidents was likely to be the result of a combination of factors, which included: the reduction in price and increased availability of relatively high-powered, handheld laser devices that had enhanced their popularity; the nationwide media coverage of these events that had heightened public awareness and increased the probability of copy-cat incidents; as well as increased reporting of illumination incidents that may have previously been ignored. The study also suggested that these incidents were more likely the careless acts of individuals, rather than deliberate criminal acts.

The total number of reported aircraft laser illuminations (845), as well as the increase in the number of laser incidents – from 46 to 451 (880%) over the 3-year study period – is troubling. However, issuance of AC 70-2 has heightened awareness of such events, created a formal procedure for reporting these incidents, and made reporting such incidents more likely. This may account for the difference in the number of reports filed for the years 2004 and 2005, when AC 70-2 was first introduced (517%), compared to the relatively small increase seen for the years 2005 and 2006 (45%). While this does not rule out an actual increase in laser activity, it could explain the disproportionate increases observed from one year to the next.

There were more than 185 million flight operations (arrivals and departures) performed during the study period. Calculating the incident rates per 100,000 flight operations provides a way to compare laser activity for specific periods of time and locations while accounting for the differences in traffic volume. The total incident rate for the U.S. was only 0.45/100,000 flight operations for the period (Figure 3). However, similar to the growth in incident frequency, the rate of laser incidents increased dramatically (i.e., 957%) during the period.

The question arises: Does an increase in flight operations result in a proportional increase in laser illuminations in a particular region? Figure 8 summarizes the percentage of operations and the incident rate (in parentheses) for each region. The figure shows that an increase in operations does not necessarily result in a proportional increase in laser illuminations. Why the incident rate in one region would differ vastly from that of another is not entirely clear. For example, the Western Pacific Region accounted for 22% of the traffic volume (40.7 million

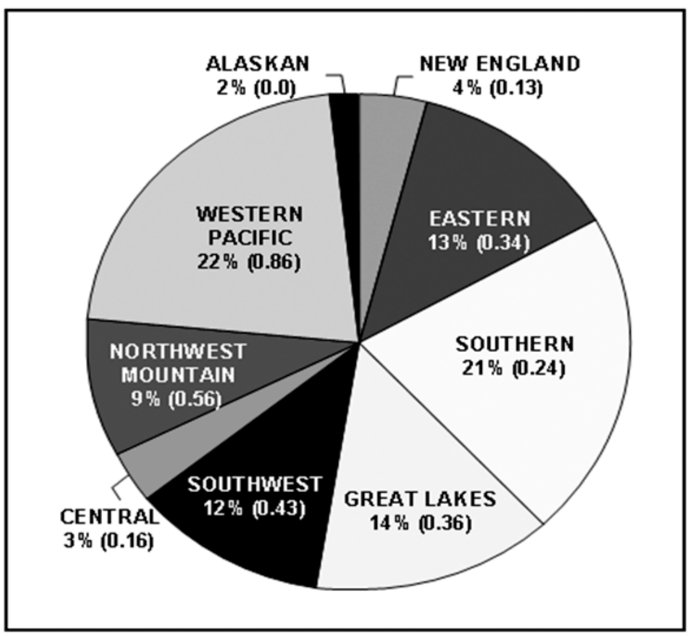


Figure 8. *The chart provides the percentage of flight operations (arrivals and departures) for the 9 regions and their incident rates for the period.*

operations) during the period and an incident rate (0.86) that was approximately 3.6X higher than that of the Southern Region (0.24) with 21% of the traffic volume (38.9 million operations).

To investigate this further, incidents and incident rates were calculated for individual airports that reported 10 or more incidents for the period (Figures 6 and 7). While the majority (52.6%) of airports reported their highest laser incident rates in 2005 (total rate = 1.99), the highest total incident rate was for 2006 (total rate = 2.56). This was mainly due to disproportionately high number of incidents reported for the San José airport, resulting in an incident rate of 40.8 – about 4.6 times higher than the Seattle/Tacoma Airport rate (8.77) in 2005, which was the next highest rate for any other airport during a single year.

The 2006 spike in laser illumination incidents at the San José airport occurred from July through mid-December 2006, with a total of 81 incidents reported. During one 3-day period (November 26-28), 20 laser incidents were reported. On December 14, 2006, police raided a residence where neighbors reported seeing a green laser beam emanate on several occasions. Although no laser device was found, no further laser incidents were reported at the San José airport for the remainder of that year. Similar clusters of incidents have been reported at other airports during the study period. These clusters occurred over various time spans, ranging from one day to several months. They often prompted action by local authorities that occasionally resulted in arrests.

The primary reason for the collection of laser incident data is to protect aircrews and the flying public. As the preceding examples illustrate, timely reporting and quick action on the local level can result in the apprehension of the perpetrator(s) and could be the best deterrent. Continued vigilance is required to prevent or curtail these careless or malicious acts.

Operational problems caused by distraction or temporary visual incapacitation could have serious consequences. A review of the safety issues associated with the current data is summarized in Table 1.

The data illustrate that cockpit illuminations can result in temporary visual effects, including glare, flashblindness, and afterimages, which may also be accompanied by temporary pain, discomfort, and even ocular injury. During the study period, 467 of the 845 laser incidents (55.3%) illuminated the cockpit environment. Fifty-two (11.1%) of these laser incidents resulted in reports of crewmembers experiencing one or more visual effects. Of these 52 incidents, 16 (30.8%) resulted in operational problems, while 11 (21.2%) resulted in temporary pain or possible injury. Operational problems can be described as anything that interferes with normal flight procedures. Reports of operational problems included: crewmembers having to avert their eyes from the laser beam, losing sight of the runway or instrument panel, relinquishing control to another crewmember, flaring the aircraft too early, performing a missed approach (go-around), and one instance in which air traffic control closed a runway due to repeated laser strikes (Houston, TX: July 2006). Although pain or possible injuries were reported in 11 incidents, the extent or duration of these effects was not retrievable. However, it is unlikely that permanent ocular injuries occurred during the study period, as it would ultimately have been reported to their AME.

Laser exposure is most hazardous when the direct laser beam enters the pupil along the axis of vision when the eye is focused on a distant object. In such cases, the energy density of a laser beam may be amplified up to 100,000 times by the eye's own optical system (12), then focused onto the retina,

Table 1. Summary of visual effects, physical effects, and operational problems reported during the study period.

YEAR	VISUAL EFFECTS			PHYSICAL EFFECTS		OPERATIONAL PROBLEM	COCKPIT ILLUMINATIONS
	GLARE	FLASH-BLINDNESS	AFTER-IMAGE	DISCOMFORT/ PAIN	POSSIBLE/ INJURY		
2004	1	6	1	2	2	3	29
2005	16	11	10	2	2	8	179
2006	1	5	1	0	3	5	259
PERIOD	18	22	12	4	7	16	467

resulting in a scotoma (retinal burn). Aiming common laser pointers over distances greater than 100 feet and striking an individual along the axis of vision would be very difficult. To achieve more than incidental contact with an aircraft's windscreen from far greater distances would likely require the aid of a telescopic sight. Even then, a laser beam projected over such distances would be subject to atmospheric attenuation, which would reduce the irradiance of all but the most powerful handheld lasers to below the MPE for brief exposure durations. As the incidents described in this report indicate, temporary visual impairment (such as glare, flashblindness, and afterimage) was the most common complaint. While eye injuries were reported, no incident is known to have caused permanent damage.

Powerful lasers capable of causing serious ocular injuries from great distances, although available to the general public, are less common due to cost (13). However, as this and other studies have shown, the resulting distraction, disorientation, or discomfort that accompanies temporary visual impairment have created hazardous situations for pilots performing critical flight operation (9, 11).

CONCLUSIONS

In conclusion, laser illumination incidents occur with some regularity within the contiguous United States. These incidents may be on the rise, and further evaluation of reported incidents is recommended to validate this hypothesis. While the data indicate the Western Pacific Region had a higher prevalence than the other FAA regions, analysis is complicated by incident clusters that can occur randomly at any airport. The incident cluster that plagued the San José airport over a 7-month period in 2006, as well as other incident clusters, typifies this phenomenon. Although operational problems are few (3.4% of all incidents), the consequences of cockpit illuminations are troubling. The most serious consequences found in this study included the closing of a runway, a missed approach, and the pilot-in-command relinquishing control of the aircraft. Incidents that resulted in potential ocular injury were rare (2.4% of all incidents), and no evidence of serious, long-term injuries was found. As laser technologies improve and become more available, the hazard to aviators may also increase. At present, prompt reporting of lasing incidents by aviators and the public, as well as quick action by local air traffic and law enforcement authorities, is the most effective deterrent against this threat to aviation safety. Should further research find these tactics to be an insufficient means of combating this problem, stricter regulation of laser products, more rigorous enforcement of laws prohibiting exposure of aircrew personnel, and training for pilots to mitigate the adverse affects of laser exposure while airborne may be necessary.

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APPENDIX A

LASER BEAM EXPOSURE QUESTIONNAIRE

FAX TO WASHINGTON OPERATIONS CONTROL CENTER(WOCC) at (202) 267-5289 ATTN: DEN

PILOT NAME________________ **PHONE NUMBER**________________

COMPANY ________________ **FLIGHT NUMBER**________________

1. Date and time (UTC) ?________________
2. Position of event (lat/long and/or FRD)? ________________
3. Altitude? ________________
4. What was the visibility? ________________
5. What were the atmospheric conditions? (Circle those which apply) – Clear, overcast, rainy, foggy, hazy, sunny.
6. What was the color(s) of the light? ________________
7. Did the color(s) change during the exposure? ________________
8. Did you attempt an evasive maneuver? ________________

   If so, did the beam follow you as you tried to move away? ________________
9. Can you estimate how far away the light source was from your location? ________________
10. What was the position of the light relative to the aircraft? ________________
11. Was the source moving? ________________
12. Was the light coming directly from its source or did it appear to be reflected off other surfaces?________________
13. Were there multiple sources of light? ________________
14. How long was the exposure? ________________
15. Did the light seem to track your path or was there incidental contact? ________________
16. What tasks were you performing when the exposure occurred? ________________

    Did the light prevent or hamper you from doing those tasks, or was the light more of an annoyance? ________________
17. What were the visual effects you experienced (after-image, blind spot, flash-blindness, glare*)? ________________
18. Did you report the incident by radio to ATC? ________________

Any other pertinant information: ________________

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This questionnaire may be filled out by the competent authority during interviews with aircrews exposed to unauthorized laser illumination. This information will be used to aid in subsequent investigation by ATC, law enforcement and other governmental agencies to safeguard the safety and efficiency of civil aviation operations in the NAS